Weather Note

THE "DOUBLE EYE" OF HURRICANE DONNA

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On the afternoon of September 6, 1960, hurricane Donna presented a striking picture on the radarscope of a U.S. Navy hurricane reconnaissance aircraft [1] as illustrated by figure 1. The structure of the inner portion of the storm as indicated by the radar was very unusual in that not only was the exact center of the storm clear of precipitation echoes but there was also a relatively wide ring in the storm interior with little or no radar return. Descriptions of the core of this storm given to the press following the flight led to newspaper stories of a "double eye," and at least one newspaper headline referred to "two-eyed" Donna. These accounts were misleading since they failed to mention that the "eyes" were concentric. In the transmitted weather reports, the storm core was described in terms of two concentric wall clouds and the inner diameter of each of the radar rings was given. As will be discussed below, this "double eye" structure persisted for at least several hours and connections between the inner and outer rings, if present, were very weak. At the time of the photographs presented in this note, hurricane Donna was located at approximately 21.5° N., 69.5° W., and was moving toward the west-northwest at a speed of about 8 kt.

A low-level penetration of the storm core was attempted from the south-southwest shortly after the time of the photograph presented in figure 1. The aircraft [2] was at an altitude near 1,000 feet and penetrated to a point about 32 miles from the center of the inner ring or just outside the edge of the outer ring. At this point the penetration attempt was abandoned because of excessive engine cooling due to the heavy rain. Surface wind speed estimates based on the state of the sea reached 100 kt. at 45 miles from the storm center and the maximum value was entered as "120+". The central sea level pressure of the storm at this time was near 940 mb.

A photograph of the scope of the vertically scanning radar taken during the attempted low-level penetration

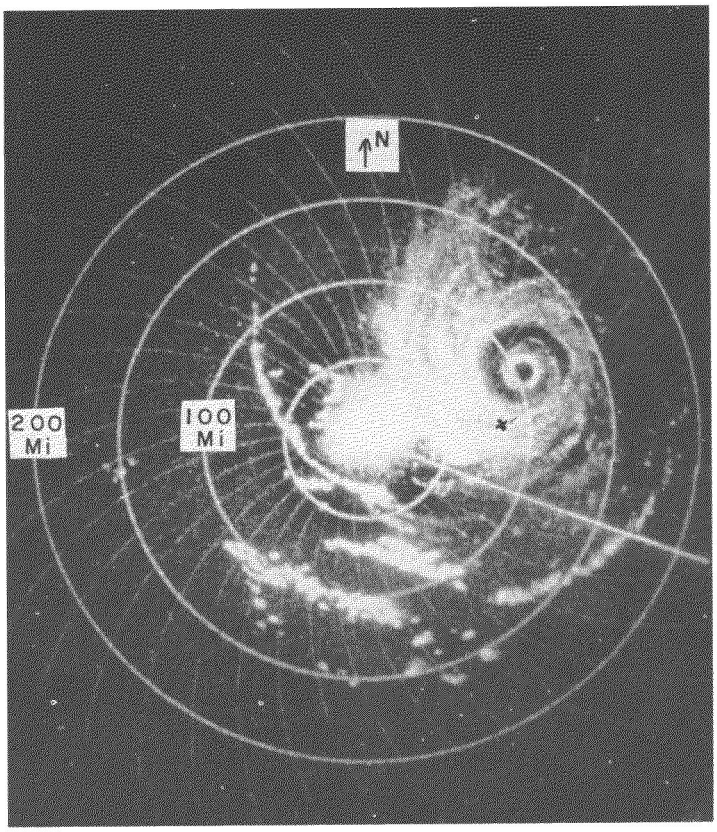

FIGURE 1.—A photograph of the scope of an APS-20E radar in a U.S. Navy hurricane reconnaissance aircraft taken at approximately 2100 GMT, September 6, 1960. The aircraft position (at the center of the photograph) was about 10 miles south of Grand Turk Island and about 105 miles west-southwest of the center of hurricane Donna. The aircraft was at an altitude of about 1500 ft. and on a heading of 110°. Some of the echoes to the south and southwest of the aircraft at a range of 75–150 miles were from the mountains of Hispaniola. The APS-20E is an S band (10.4 cm.) radar with a peak power of 2.0 megawatts. The beam width, as defined by the half-power points, is approximately 1.5° in the horizontal and 6.0° in the vertical. The symmetrical spiralling pattern of light lines was due to interference from other electronic equipment.

[1] Of the Airborne Early Warning Squadron Four then located at the Naval Air Station, Jacksonville, Fla.

[2] The aircraft was of the Super Constellation type, U.S. Navy designation WV-3.

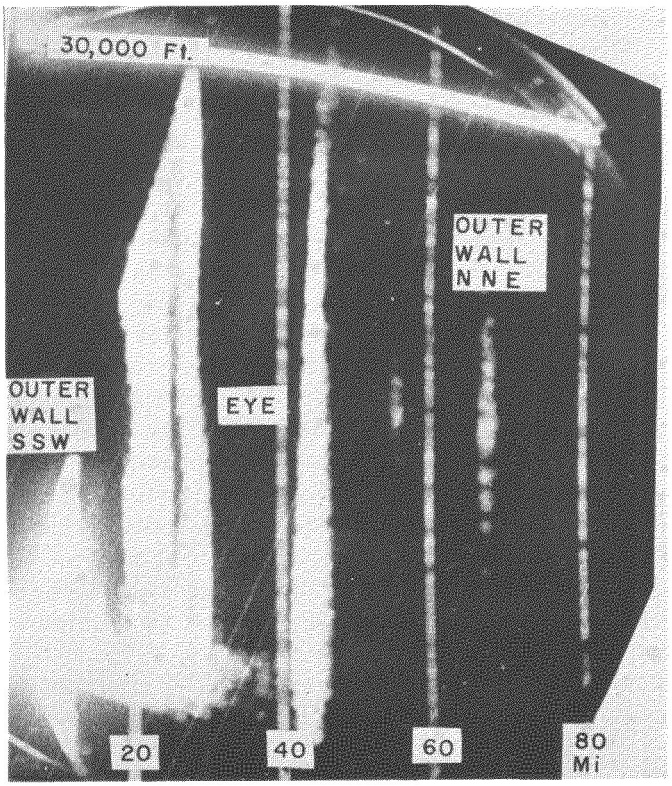

FIGURE 2.—A photograph of the range-height scope of the APS–45 radar in a U.S. Navy hurricane reconnaissance aircraft taken about 30 minutes after figure 1. Height is shown on the vertical scale and slant range from the aircraft on the horizontal scale. The aircraft was at a relative position given approximately by "x" on figure 1 and was at an altitude of about 1,000 ft. The view is directly across the storm center toward the north-northeast. The APS–45 is an X band radar (3.2 cm.) with a peak power of 450 kilowatts. The beam width, as defined by the half-power points, is approximately 3.0° in the horizontal and 1.0° in the vertical.

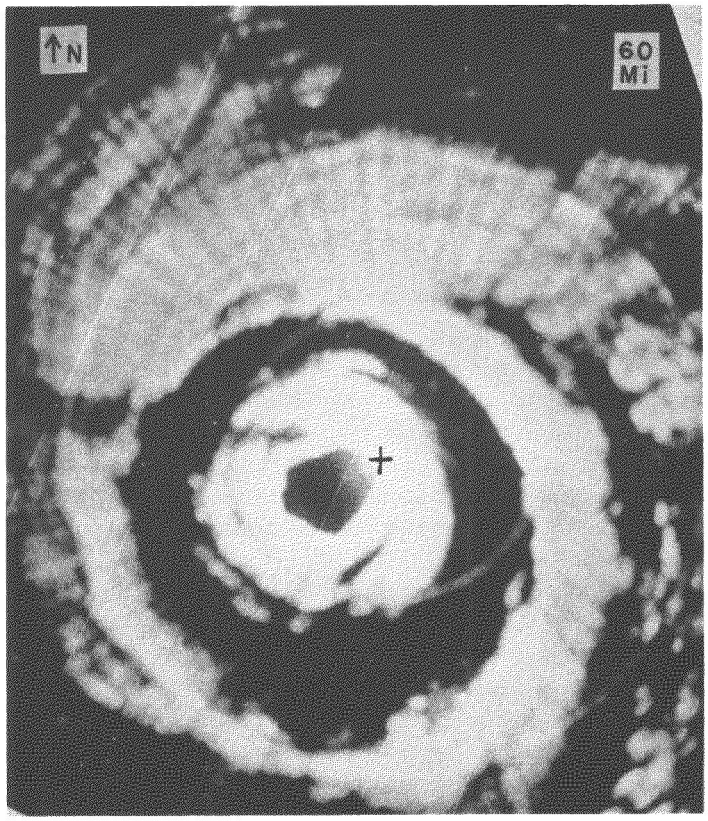

FIGURE 3.—A photograph of the plan-position scope of the APS–45 radar taken at approximately 2215 GMT, September 6, 1960. The aircraft was at the position indicated by the "+" and at an altitude of about 8,300 ft. The 20-mile and 40-mile range circles to the southeast of the center and the 60-mile circle in the north-northeast sector can be seen faintly.

(fig. 2) gives additional information on the structure of the storm core. This range-height view, taken from a relative position indicated by the "x" in figure 1, was directed across the eye from south-southwest toward north-northeast. The cross-section of the inner ring is clearly shown but, because of attenuation, the outer ring on the opposite side is barely discernible. This radar, the APS–45, is subject to much greater attenuation than the APS–20E, from which figure 1 was obtained, because of the shorter wavelength which is used. The inner wall cloud is shown on the range-height scope as nearly vertical and the echoes extend above 30,000 ft. The diameter of this inner "eye" varied from about 10 miles at the lower level to about 13 miles at the high levels.

The "clear" zone between the inner and outer rings on figure 2 is confused to some extent on the side nearest the aircraft by return from the sea which shows up in the form of a horizontal fanshaped pattern. The small faint echo in the "clear" space on the far side of the inner ring should perhaps be associated with the small echo in the same region on figure 1. The time difference of the two photographs is only about 30 minutes.

The radar appearance of the inner ring was more characteristic of convective type echoes than the outer one and it extended to somewhat greater heights. The maximum height of the inner ring during the several hours that it could be seen on this flight was about 45,000 ft., while the clouds forming the outer ring appeared to be more stratiform in character and gradually died out on the range-height scope above 30,000 ft. In view of the greater strength and height of the inner echo, it could be argued that, at this time, the inner radar ring should be considered as the true wall cloud of the eye.

Following the low-level penetration attempt, a climb to the 700-mb. level was made and the storm core was penetrated from the northeast with relatively little difficulty. The space between the radar rings was free of clouds in a layer which was estimated to extend from about 3,000 ft. to about 25,000 ft. However, only a limited area was visible during the penetration and, un-

fortunately, the exit was made after dark. The stratocumulus between the two radar rings consisted of well-formed concentric horizontal rolls and appeared to be unusually low. The ocean surface was not visible through the stratocumulus so that we have absolutely no information on the distribution of wind between the inner and outer rings. Unfortunately, the research aircraft of the National Hurricane Research Project did not enter Donna on this day.

There was a thick layer of cirrus or high altostratus extending out from the inner core and covering the area between the two rings. The inner core of the storm was described by one of the pilots as resembling a giant "tastee freeze". Inside the inner ring, the stratocumulus was nearly overcast but the sea surface could be seen in spots. Cirrus was absent over most of the inner "eye" and there were no clouds above the stratocumulus which, in this area, extended to about 6,000 ft.

A photograph of the APS–45 scope taken during the penetration of the inner radar ring (while the radar was on horizontal scan) is shown in figure 3. The "clear" ring shows up nicely but it is shown as being somewhat narrower than indicated in figure 1. This difference is not surprising in view of the shorter wavelength of this radar and the fact that the aircraft was much closer to the cloud systems. The narrowest portion of the "clear" ring and the greatest suggestion of a connection is shown on the north side of the center. This is almost directly opposite to what was shown in figure 1 but there is a time difference of a little more than 2 hours between these two photographs.

The "double eye" structure was observed throughout a period of about 5 hours when the afternoon flight of September 6 had the hurricane on its radar. The inner ring appeared to be weakening as the aircraft moved away from the storm but it was noted on the subsequent flight a few hours later. Limited information is available from this later flight because the radar was not functioning properly. The eye reorganized during the night and on the following day an orthodox eye was found with a diameter of about 25 miles. About 12 hours prior to the time of figures 1 and 2, there was no evidence of a "double eye" and the eye diameter was reported as 20 miles.

A rather poorly documented case of a "double eye" was reported in a hurricane of 1947 [3] and the same type of structure has been reported in several typhoons in recent years. Fortner [1] described typhoon Sarah of 1956 at the time when it had "an eye within an eye". In some of the spectacular typhoon cases, the inner convective system appears as a giant cumulonimbus centered in a large "eye". The "inner eye" within the cumulonimbus vortex has been observed to be as small as 2 miles. In these cases, winds well in excess of typhoon force were observed in the relatively clear space separating the inner and outer wall clouds. In other cases in recent years [2], the radar has indicated a very narrow ring of relatively weak return just outside a ring-shaped wall cloud but these weak areas were not apparent from visual observations made from the reconnaissance aircraft.

To our knowledge, all cases of "double eyes" in intense tropical cyclones have been of the concentric type. There are often radar features, the so-called "false eyes", outside the storm core which could be misinterpreted as the eye of the storm by inexperienced observers. These, however, do not have closed circulations about them and are hardly detectable, if at all, in the wind and pressure fields.

REFERENCES

1. L. E. Fortner, Jr., "Typhoon Sarah, 1956," *Bulletin of the American Meteorological Society*, vol. 39, No. 12, Dec. 1958, pp. 633–639.
2. C. L. Jordan, D. A. Hurt, Jr., and C. A. Lowrey, "On the Structure of Hurricane Daisy on 27 August 1958," *Journal of Meteorology*, vol. 17, No. 3, June 1960, pp. 337–348.
3. U.S. Navy, "A Note on the Double Eye Phenomena as Observed During Hurricane 11–20 Sept. 1947," *NAVAER* 50–IR–207, Chief of Naval Operations, Washington, D.C., 11 pp.